US Army Corps of Engineers.

Economic Aspects / Implications of Risk & Reliability of Coastal Structures on the Great Lakes

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Buffalo District
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O&M Budget Issues of Great Lakes

US Army Corps of Engineers.

- Recent GL O&M budget is flat at best
- GL System O&M needs and expenses are rising
- We now need to demonstrate return on investment to OMB for proposed O&M expenditures
- Incorporate asset management principles considering risk & reliability

Risk Assessment

US Army Corps of Engineers.

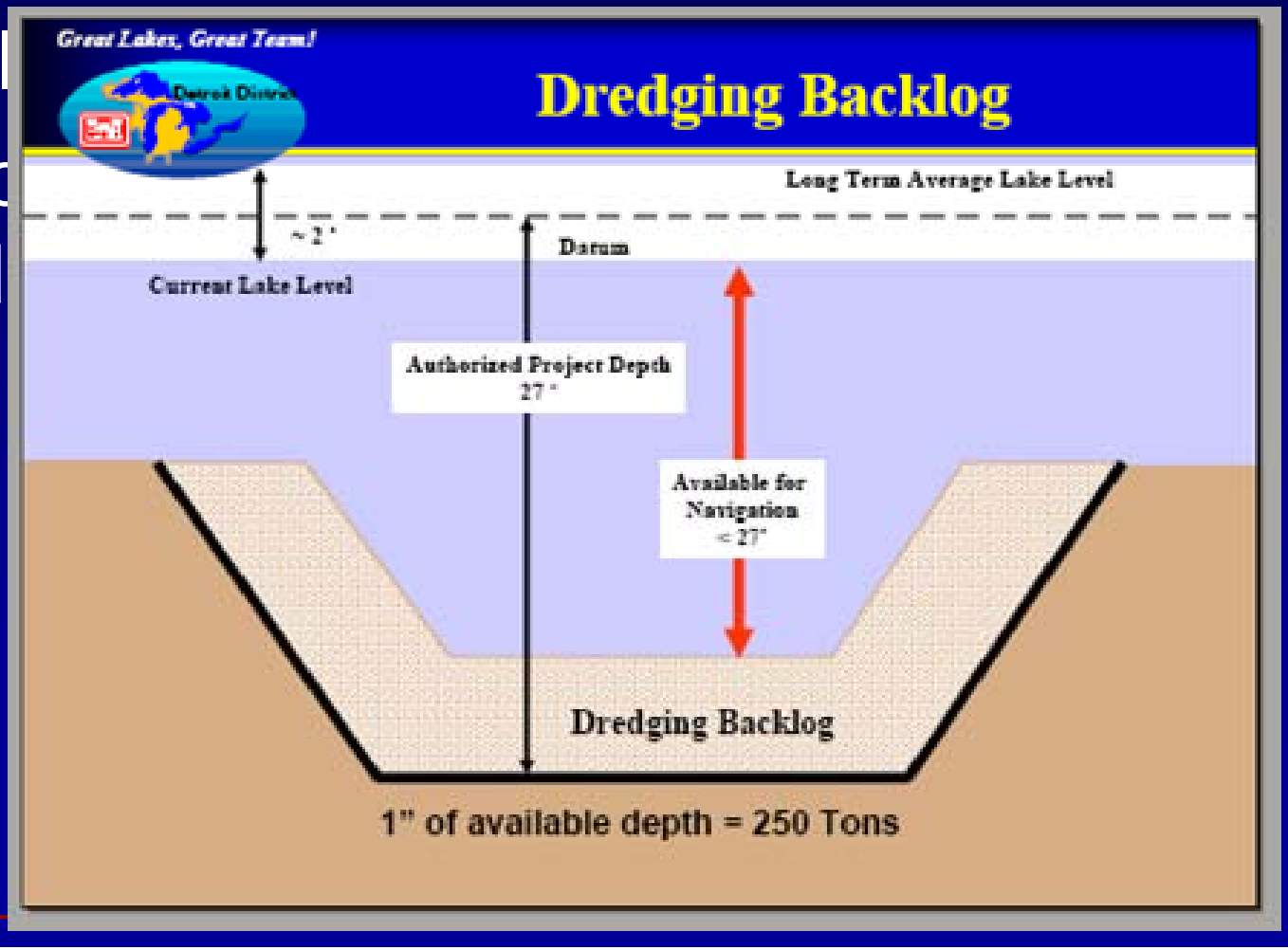
- Risk assessment is a science-based, systematic process for quantifying and describing the nature, likelihood and magnitude of risk associated with some substance, situation, action or event, including consideration of relevant uncertainties.

  - *Adding up the probabilities of possible "bad things" happening multiplied by the $ value of the corresponding consequence.*

Economic Issues of GL Risk & Reliability Overview

US Army Corps of Engineers.

- Channel depth loss from shoaling
- Availabil
- Failure c
  age and
  attack



Challenge: Aging Infrastructure

US Army Corps of Engineers.

- Many navigation structures are greater than 100 years old
- Too few dollars chasing too many needs

Summary of Ave Annual Maintenance – Buffalo District

US Army Corps of Engineers.

- About million CY at 10 harbors dredged annually
- Up to 2,000 linear feet of navigation structures repaired by floating plant
- Approx 1 major construction contract let for repairing navigation structures ($1-3M)

Budget Wonk Questions

US Army Corps of Engineers.

- Is a particular repair or rehabilitation project a good use of federal funds?
- Is the expected value of benefits greater than the cost of repair?
- How can we prioritize all the proposed projects on the list?

Coastal Structures (with Potential Economic Consequences)

US Army Corps of Engineers.

- Breakwaters
  - Rubble mound stone
  - Laid up stone
  - Core-Loc
- Jetties/Piers
- CDF's

Virtually any federal structure

Consequences of Inadequate Maintenance

US Army Corps of Engineers.

- National Economic Impacts
  - Increased transportation costs
  - Increased damages
  - Increased nonfederal maintenance and repair
  - Lost recreation opportunities
- Regional Development Impacts
  - Loss of Jobs
  - Loss of Income
  - Loss of Revenue
- Environmental Consequences
  - Increased Water & Air Pollution
  - Risk to habitat and species

Commodity	Jobs/1000 tons
Steel Products	1.07
General Cargo	0.33
grain	0.22
iron ore	0.22
Coal	0.15
Cement	0.21
Aggregates,limestone	0.20
Petroleum	0.30
Others	0.11
Chemicals	0.51
Ores&minerals	0.20

- Safety – Loss of Life!!!

Need to Evaluate in Planning Setting

US Army Corps of Engineers.

- Establish Project Evaluation Period
  - (e.g. 50 years, 20 years, etc.)
- Establish Existing & Future WOPC (What is the future if we continue to operate and maintain the projects in the same manner as we have in the past?)
- Establish Existing & Future WPC's

Engineering Inputs

US Army Corps of Engineers.

- Probability of failure
- Type of failure, given it failed
- Repair costs
- Time required for repairs
- Effect of repair on future reliability
- Event tree that shows linkages between 1-5.

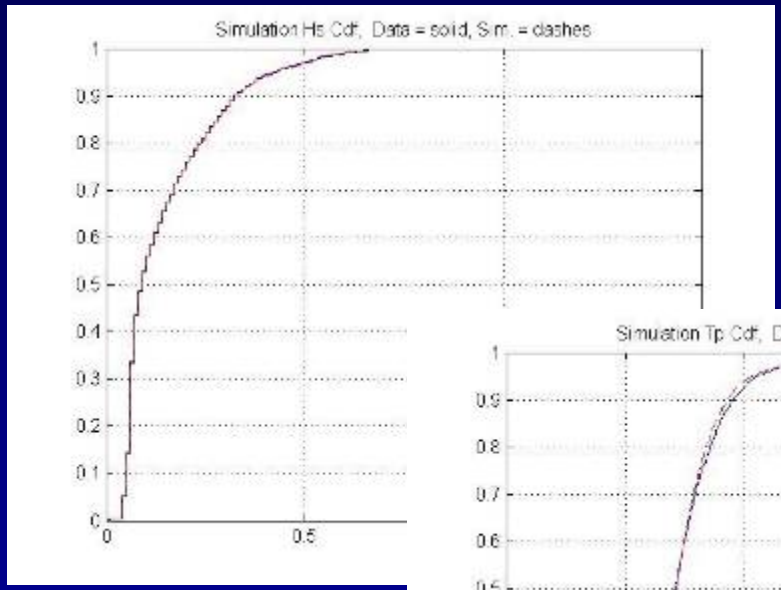
Reliability

US Army Corps of Engineers.

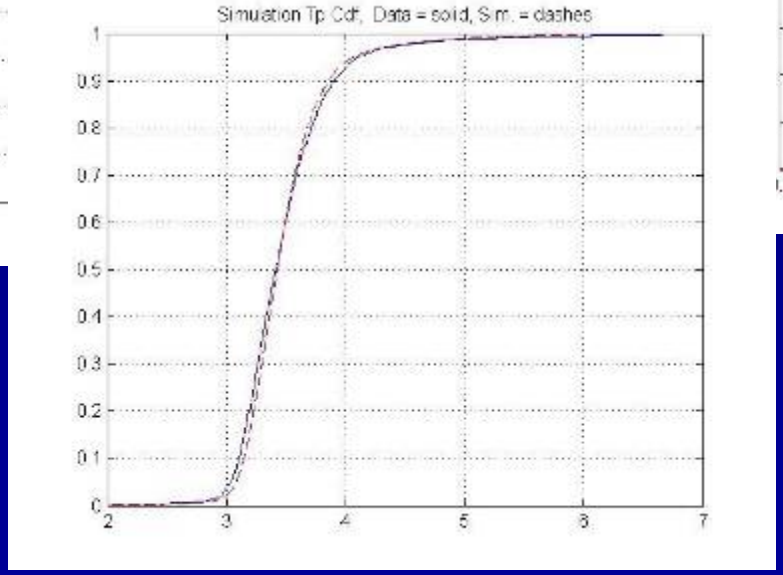
- Probability of failure over time.
- Probability of failure in a specific year given it survived to that year – hazard value.
- Developed by BAT Team and Coastal engineering staff based on expert opinion.

Cumulative Distributions Historical and ELS (ERDC)

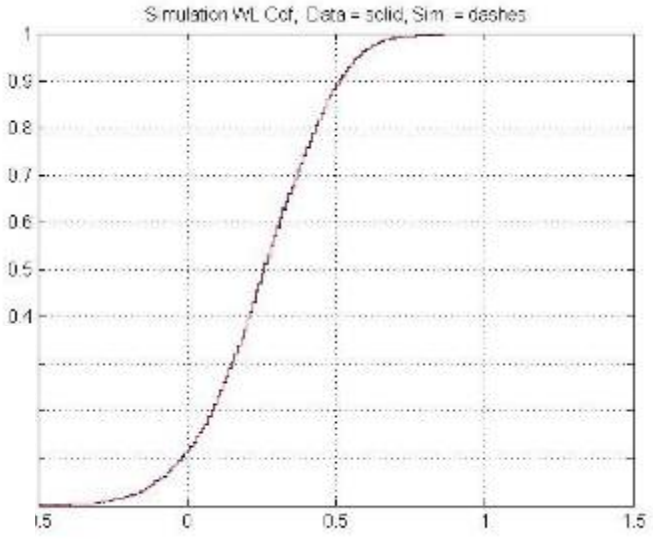
US Army Corps of Engineers.



Wave Height, Hs



Peak Wave Period, Tp



Water Level, h

Event Tree Analysis

US Army Corps of Engineers.

- Event tree analysis is based on binary logic, in which an event either has or has not happened or a component has or has not failed.
- It is valuable in analyzing the consequences arising from a failure or undesired event.

Event Tree

US Army Corps of Engineers.

- An Event Tree starts from an undesired initiator (e.g. component failure, etc) and follows possible further system events through to a series of final consequences.
- As each new event is considered, a new node on the tree is added with a split of probabilities of taking either branch.
- The Event Tree is the foundation of a simulation model.
- Developed by BAT Team and Coastal Engineering Staff.

Event Tree for Generic Coastal Structure Link reliability with consequences

US Army Corps of Engineers.

Wave Height Exceedance Probability	Probability of Unsatisfactory Performance	Performance Level Probability	Branch Probability	Consequences ($)

For Frequent but Less Damaging Event

5 ft
50.00%

Pr(u) (Unsatisfactory Perf.)
0.00036%

Reliability (Satisfactory Performance)
99.99964%

Impacts w/o Failure (minor damage to structure)
99.00%
0.00018%

Harbor Damages (Docks and
Repair & Cleanup Costs
Navigation Delay Costs
Infrastructure Losses from Erosion
and Coastal Storm Damage

Failure (major damage to structure)
1.00%
0.00000%

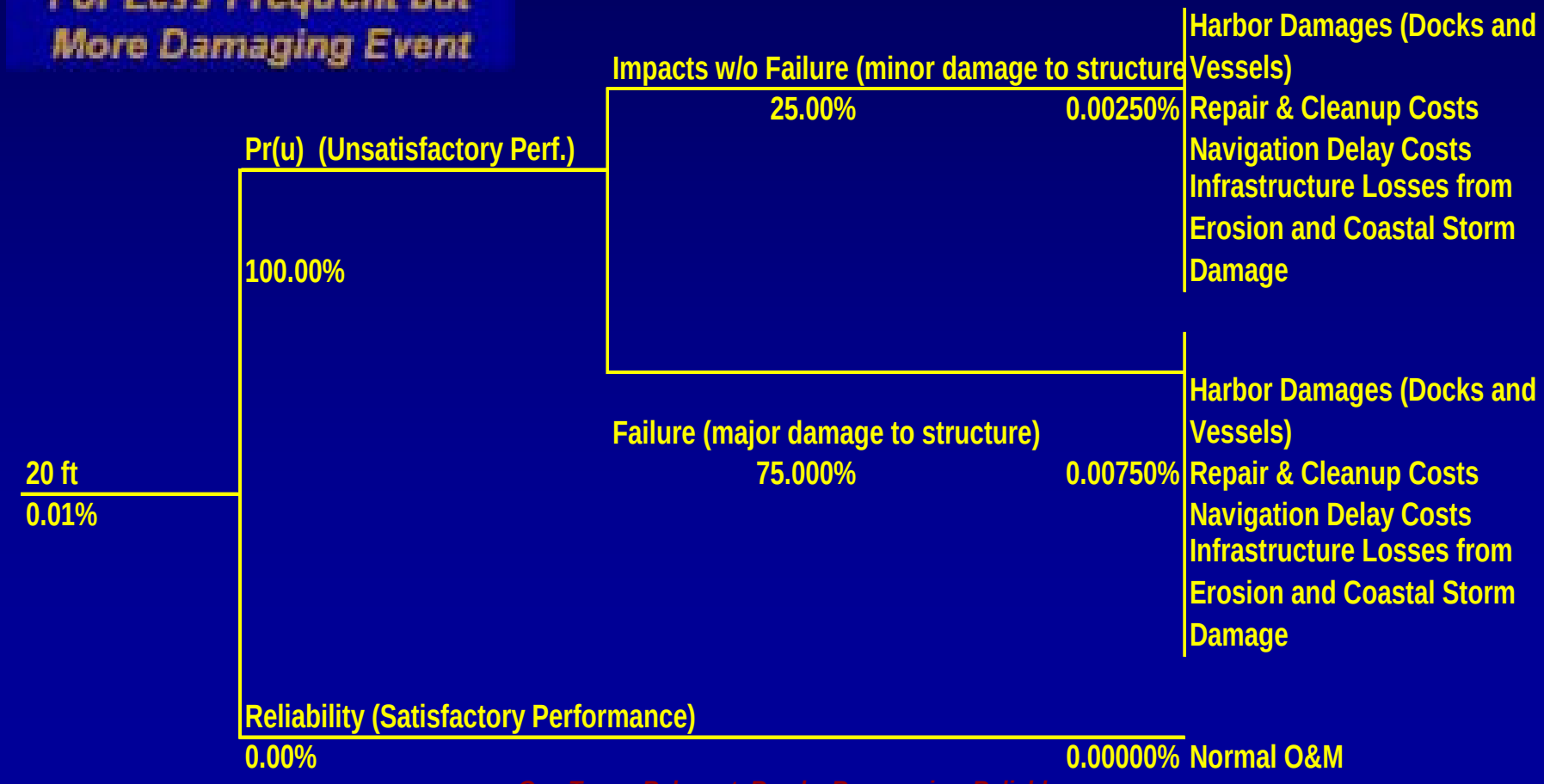
Harbor Damages (Docks and
Repair & Cleanup Costs
Navigation Delay Costs
Infrastructure Losses from Erosion
and Coastal Storm Damage

49.99982% Normal O&M

Event Tree for Generic Coastal Structure Link reliability with consequences

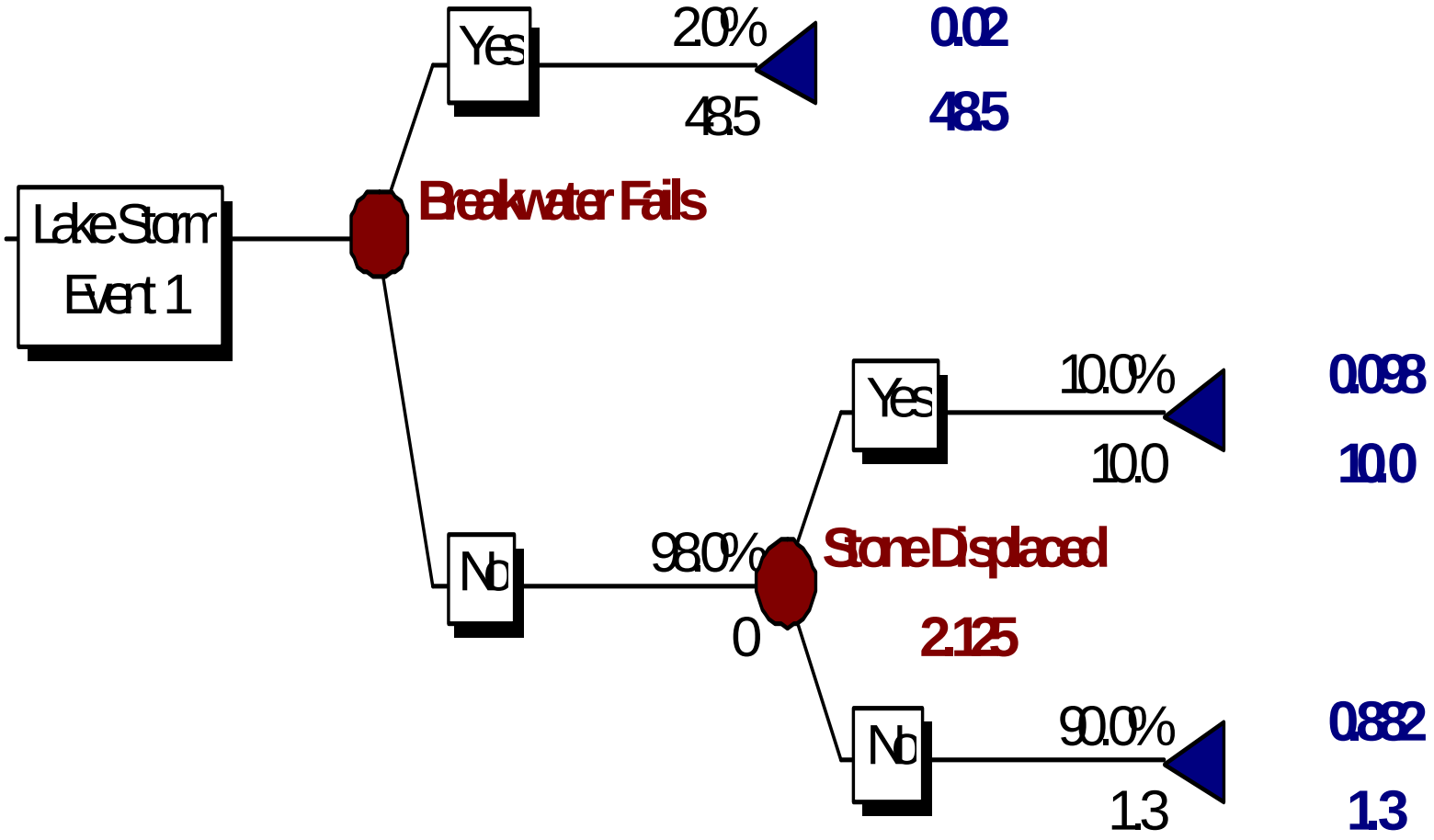
US Army Corps of Engineers.

For Less Frequent but More Damaging Event



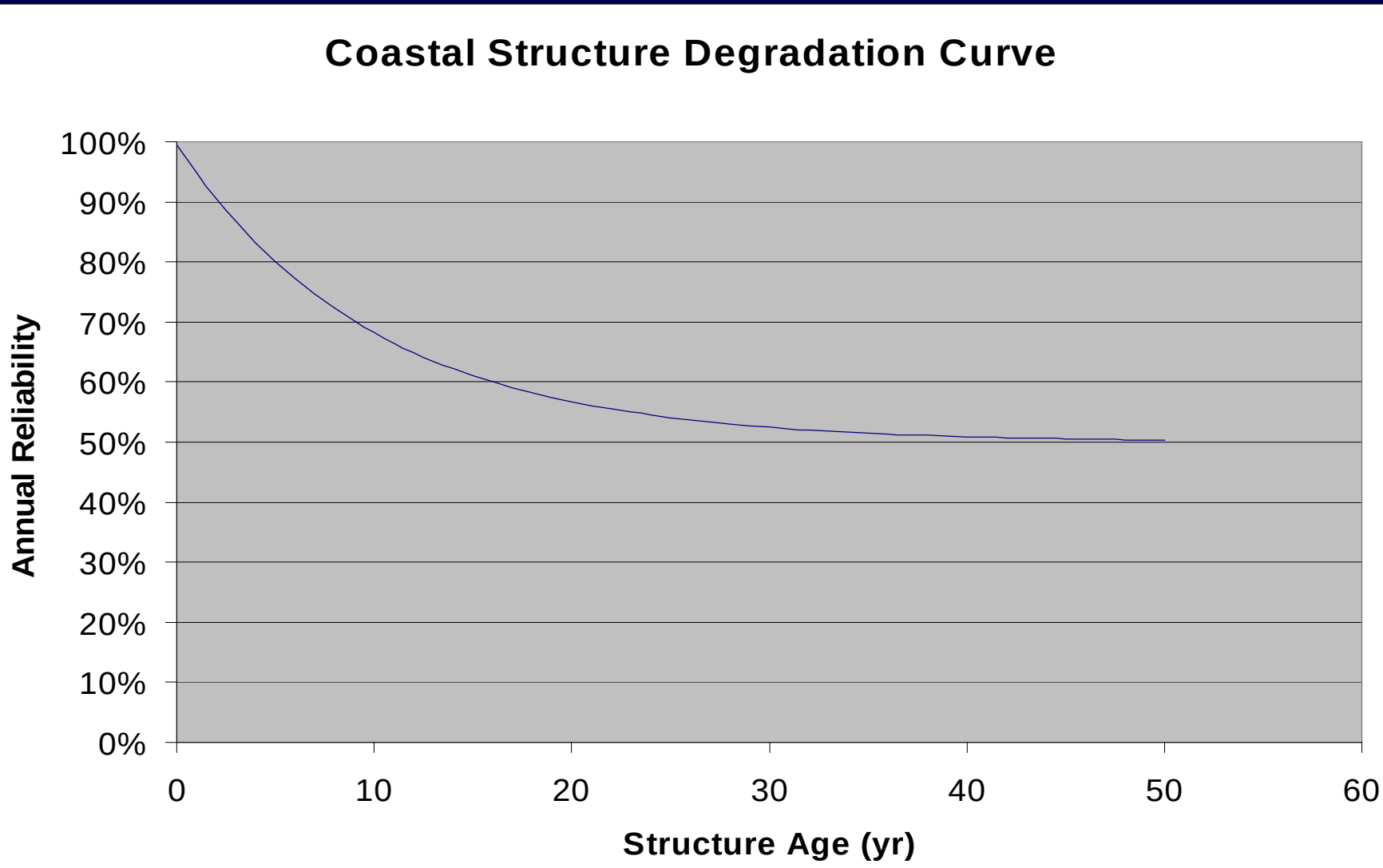
Event Tree Possibilities

US Army Corps of Engineers.



Degradation Curve

US Army Corps of Engineers.



Monte Carlo Simulation Model

US Army Corps of Engineers.

- Model duplicates event tree logic fifty times for fifty future years and links what happens in one year with the following year.
- Model generates random numbers to determine the path followed in any one year.
- Model can perform the multi-year simulation a large number of times.
- @Risk© for Excel© Model developed by economist in Pittsburgh.

Simulation Process

US Army Corps of Engineers.

Simulation – Simulate possible events as depicted in Event Tree

Event Tree

Life Cycle Analysis – Multiple Simulations of Event Tree

Event Tree - - - - - - - - - - - - - Event Tree

2009 2058

Iterations – Multiple Life Cycle Runs

Life Cycle Analysis - 1

Event Tree … Event Tree

2009 2058

Life Cycle Analysis - 2

Event Tree … Event Tree

2009 2058

Etc.

Probability of Failure in "Without" Condition (hazard value)

US Army Corps of Engineers.

Year	Probability of Failure
2009	5%
2020	20%
2058	50%

Economic Consequences of Failure

US Army Corps of Engineers.

Year	Damage
2009	$100
2020	$100
2058	$100

Expected Economic Costs "Without" Condition

US Army Corps of Engineers.

Year	Expected Value
2009	5% x $100 = $5
2020	20% x $100 = $20
2058	50% x $100 = $50

Alternatives ("With" Conditions)

US Army Corps of Engineers.

1. Major Rehab- Rubblemound Structure

2. Major Repair

Probability of Failure in "With" Condition (hazard values)

US Army Corps of Engineers.

Year	Probability of Failure
2009	1%
2020	5%
2058	10%

Economic consequences of Failure

US Army Corps of Engineers.

Year	Damage
2009	$100
2020	$100
2058	$100

Expected Economic Costs "Without" Condition

US Army Corps of Engineers.

Year	Expected Value
2009	1% x $100 = $1
2020	5% x $100 = $5
2058	10% x $100 = $10

Benefits

US Army Corps of Engineers.

Year	"Without"	"With"	Benefit
2009	$5	$1	$4
2020	$20	$5	$15
2058	$50	$10	$40

Annualize Benefits

US Army Corps of Engineers.

- Discount value in each year to present value equivalent.
- Sum present value equivalents.
- Amortize cumulative present value which yields the average annual equivalent benefit.

Economic Analysis using Monte Carlo Risk Model

US Army Corps of Engineers.

- Simulation starts with first year (under WOPC).
- Simulation continues for each year in PEP.
- Computer stores results for this iteration.
- Process continues for several iterations.
- Maybe do for “with”, depending if fix does not make project completely reliable.
- Subtract residual damages under “WPC” from those of “WOPC” to compute benefits.
- Compare benefits with costs to determine net Benefits and BCR.

Economic Consequences How to get good data?

US Army Corps of Engineers.

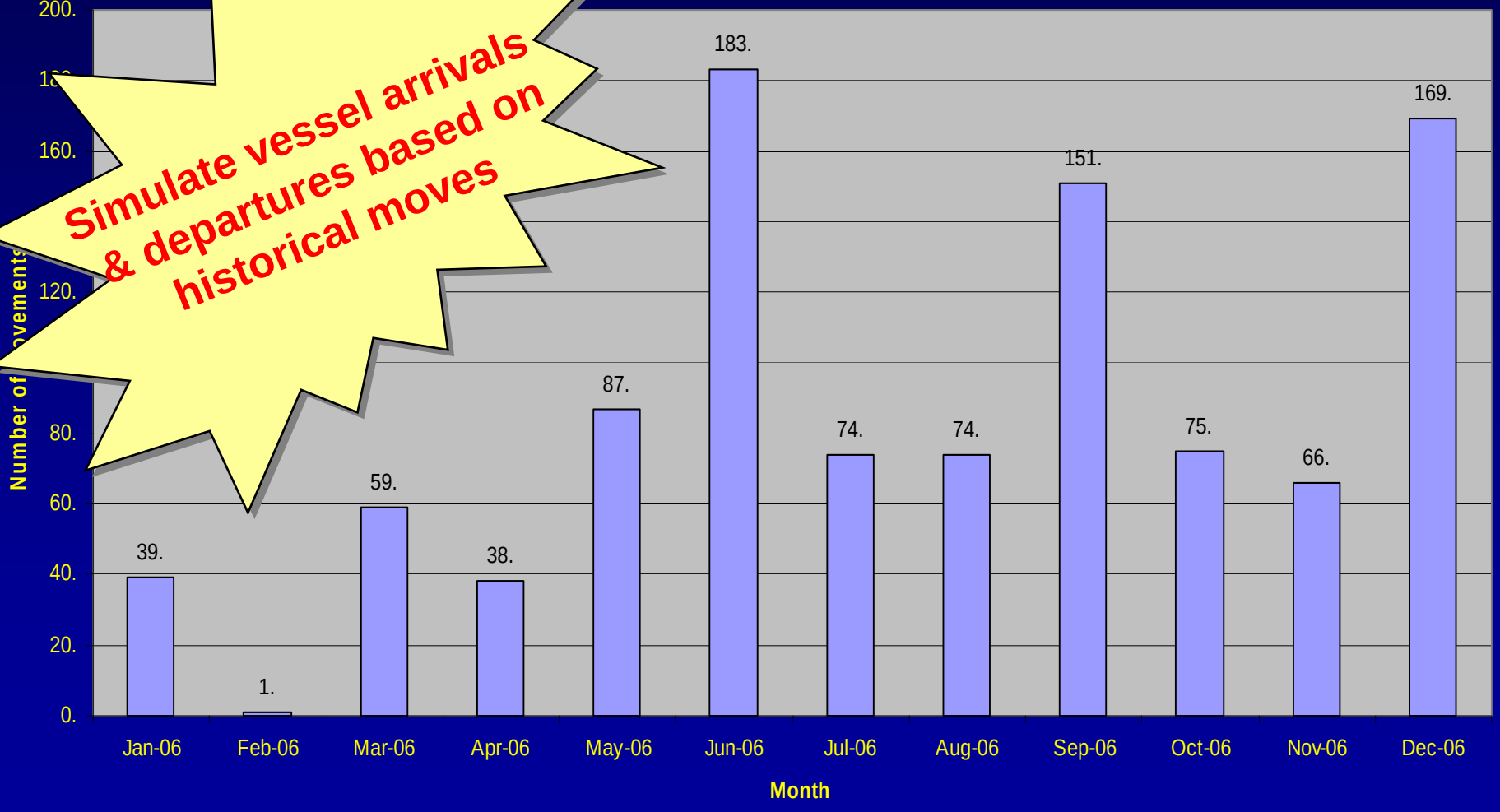
- By Harbor, Develop Threshold Wave Height - Delay by Vessel Relationship
- Conduct Shipper Response Surveys
- Estimate Induced Shoreline Maintenance Under Disrepair Scenarios
- Develop Erosion Rates

Cleveland Harbor Movements 2006

US Army Corps of Engineers.

Cleveland Harbor Movements
CY 2006

Simulate vessel arrivals & departures based on historical moves



GL Vessel Operating Costs

US Army Corps of Engineers.

Hourly Delay Costs

Vessel Class	Cost / Hour*
• Class 5 (600-649 ft)	$1,974
• Class 7 (700-730 ft)	$2,086
• Class 10 (950-1,099 ft)	$2,939

*FY08 Price Level

Measuring Economic Consequences

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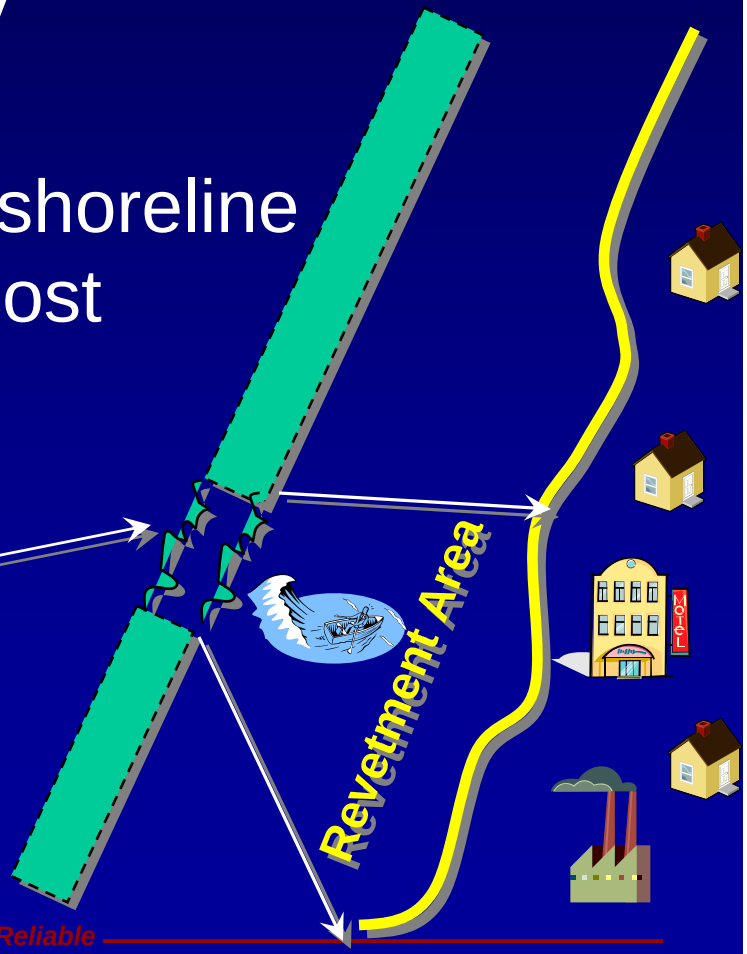
- As a proxy for potential infrastructure coastal damage, use revetment cost for linear reach affected by breakwater breach
- Linear feet of unprotected shoreline times $ / ft of revetment cost



Breach from Storm Event

Other Consequences

US Army Corps of Engineers.

- Breakwater Damage Cleanup Cost
- Repair Cost (Fix as Fails)
- Damage to boats, docks, and other shoreline infrastructure
- Increased Shoaling (Dredging Requirement)

Evaluating Coastal Structures: Problems & Needs

US Army Corps of Engineers.

- Insufficient data to make informed decisions
  - Physical Cause/Effect & Probability of Occurring
  - Economic Response & Measurement
- Refine tools for measuring impacts
  - Risk Analysis Model

Consequence of High Risk Level

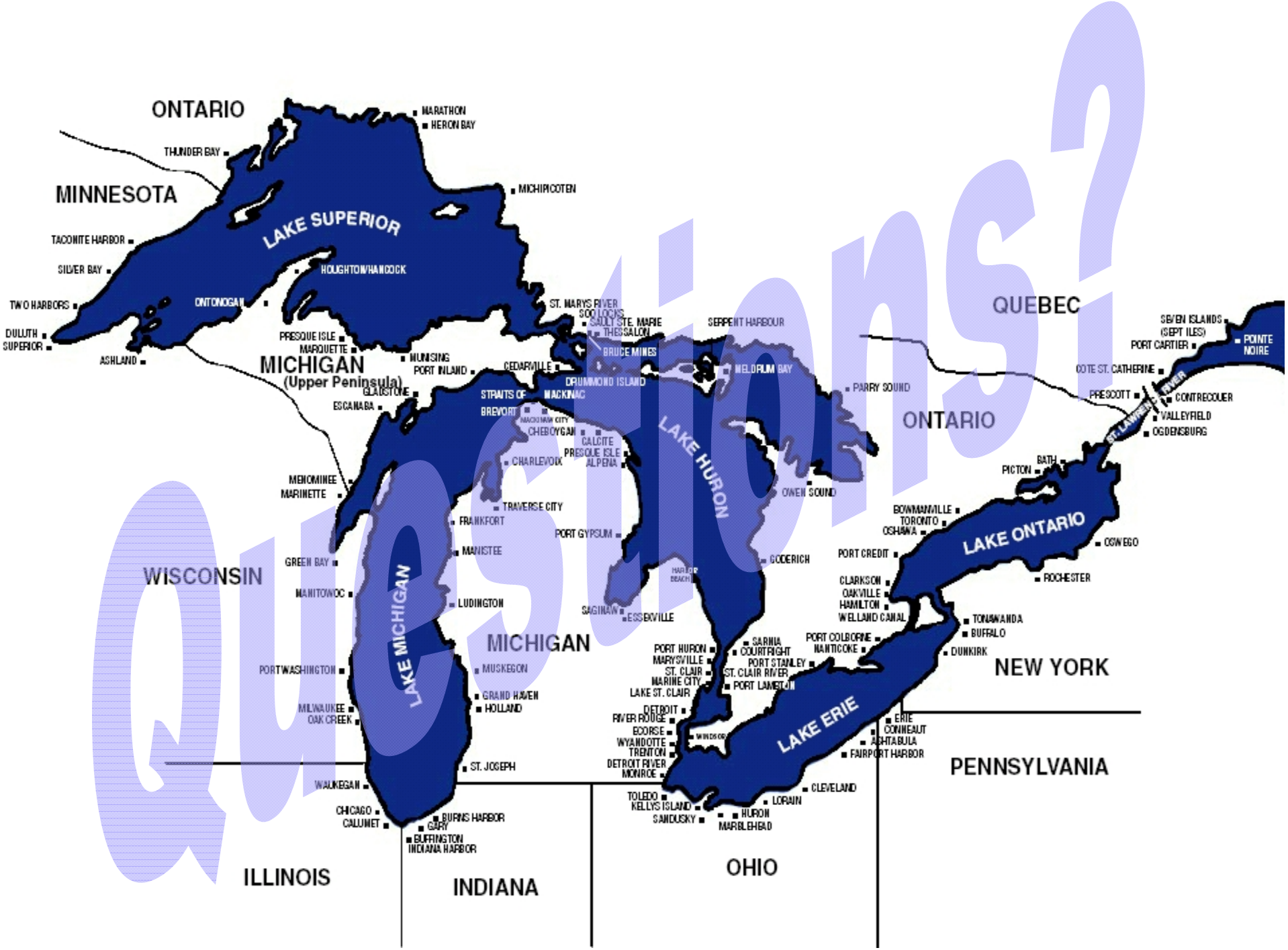
US Army Corps of Engineers.

- Increased transportation costs
- Loss of industry, jobs and revenue
- Shift from waterborne to land-based transportation
- Increased air pollution & rail & highway accidents

Huge Complex Effort

US Army Corps of Engineers.

- Improving the level of data available
- Developing assessment metrics
- Develop evaluation methods
- Develop computer models
- Develop Nontraditional benefits


ONTARIO
MARATHON
HERON BAY
THUNDER BAY
MINNESOTA
MICHIPICOTEN
LAKE SUPERIOR
TACONITE HARBOR
SILVER BAY
HOUGHTON/HANCOCK
TWO HARBORS
ONTONAGAN
DULUTH
SUPERIOR
ASHLAND
PRESQUE ISLE
MARQUETTE
MUNISING
MICHIGAN
(Upper Peninsula)
PORT INLAND
GLADSTONE
ESCANABA
ST. MARYS RIVER
SOO LOCKS
SAULT STE. MARIE
THESSALON
BRUCE MINES
CEDARVILLE
DRUMMOND ISLAND
STRAITS OF MACKINAC
BREVORT
MACKINAW CITY
CHEBOYGAN
CALCITE
PRESQUE ISLE
ALPENA
CHARLEVOIX
MENOMINEE
MARINETTE
TRAVERSE CITY
FRANKFORT
PORT GYPSUM
MANISTEE
GREEN BAY
WISCONSIN
MANITOWOC
LUDINGTON
LAKE MICHIGAN
MICHIGAN
PORT WASHINGTON
MUSKEGON
GRAND HAVEN
HOLLAND
MILWAUKEE
OAK CREEK
ST. JOSEPH
WAUKEGAN
CHICAGO
CALUMET
BURNS HARBOR
GARY
BUFFINGTON
INDIANA HARBOR
ILLINOIS
INDIANA
SERPENT HARBOUR
MELDRUM BAY
PARRY SOUND
LAKE HURON
OWEN SOUND
GODERICH
HARLOW BEACH
SAGINAW
ESSEXVILLE
PORT HURON
MARYSVILLE
ST. CLAIR
MARINE CITY
LAKE ST. CLAIR
DETROIT
RIVER ROUGE
ECORSE
WYANDOTTE
TRENTON
DETROIT RIVER
MONROE
TOLEDO
KELLYS ISLAND
SANDUSKY
SARNIA
COURTRIGHT
PORT STANLEY
ST. CLAIR RIVER
PORT LAMBTON
WINDSOR
HURON
MARBLEHEAD
LORAIN
CLEVELAND
OHIO
QUEBEC
SEVEN ISLANDS
(SEPT ILES)
PORT CARTIER
POINTE NOIRE
COTE ST. CATHERINE
PRESCOTT
CONTRECOEUR
VALLEYFIELD
OGDENSBURG
ST. LAWRENCE RIVER
ONTARIO
BATH
PICTON
BOWMANVILLE
TORONTO
OSHAWA
LAKE ONTARIO
OSWEGO
PORT CREDIT
ROCHESTER
CLARKSON
OAKVILLE
HAMILTON
WELLAND CANAL
TONAWANDA
BUFFALO
PORT COLBORNE
NANTICOKE
DUNKIRK
NEW YORK
LAKE ERIE
ERIE
CONNEAUT
ASHTABULA
FAIRPORT HARBOR
PENNSYLVANIA